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OPTIMUM TRACK SHIP ROUTING (OTSR) APPLICATIONS OF THE TROPICAL --ETC(U)

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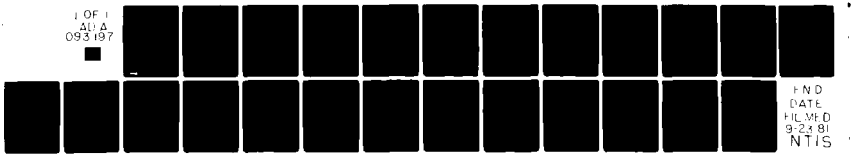

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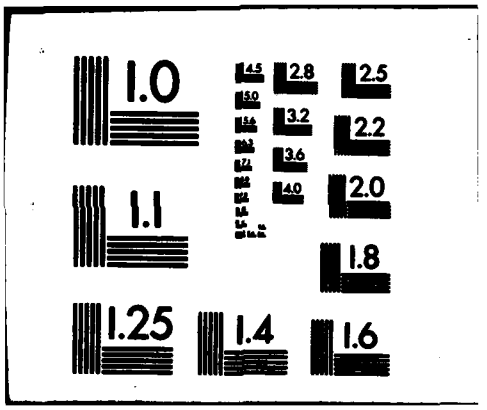
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OPTIMUM TRACK SHIP ROUTING (OTSR) APPLICATIONS OF THE TROPICAL CYCLONE STRIKE/WIND PROBABILITY PROGRAM

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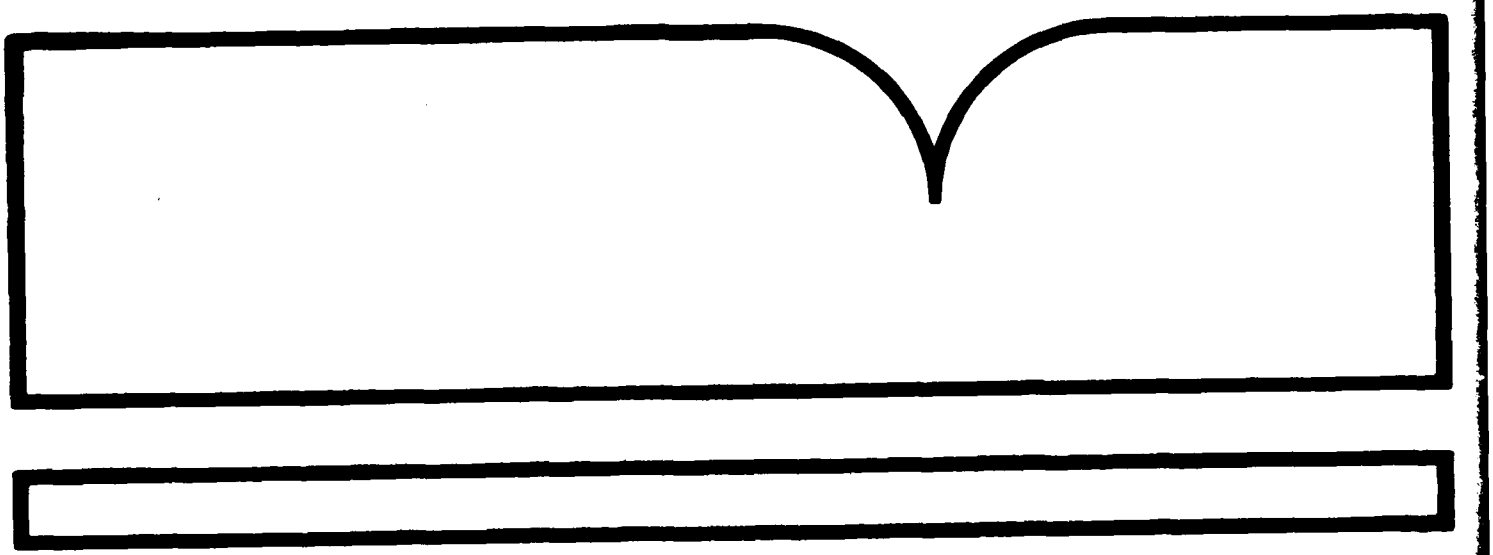

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Optimum Track Ship Routing (OTSR) Applications of Strike Probability (OASP) system of computer programs is described. This system utilizes a method of forecasting the probabilities of encountering 30 kt and 50 kt tropical cyclone winds in the western North Pacific Ocean based on the tropical cyclone warnings issued by the Joint Typhoon Warning Center (JTWC), Guam, and the statistical analysis of historical tropical cyclone forecast errors. By applying this method of forecasting tropical cyclone wind probabilities,

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incorporating ship track evaluation and route generation algorithms, ard including interactive and remote display capabilities, the OTSR personnel at the Fleet Numerical Oceanography Center, Monterey, California, and other users are provided with a unique approach to the display, evaluation, and routing of ships threatened by tropical cyclones.

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SECTION 1. INTRODUCTION

The Optimum Track Ship Routing (OTSR) Applications of Strike Probability (OASP) system of computer programs was developed for the Naval Environmental Prediction Research Facility (NEPRF) to assist ship routing personnel in the performance of their duties. This system provides OTSR personnel and other users at the Fleet Numerical Oceanography Center (FNOC) with a near real-time evaluation of the tropical cyclone wind threat to ships under OTSR. The system also provides the user at FNOC with various display, evaluation, and route generation capabilities on a local interactive graphics terminal. In addition, display information may be acquired remotely via an Automatic Response to Query (ARQ) request on the Naval Environmental Display Station (NEDS)[1].

1.1 Background. The strike probability concept is based on statistical analyses of historical western North Pacific Ocean tropical cyclone forecast errors and is documented in references [1] and [2]. A computer program, called STRIKP, which forecasts the tropical cyclone strike probabilities for geographic points of interest in the western North Pacific was developed using the above concept. The STRIKP program was subsequently expanded to include the capability of forecasting tropical cyclone wind probabilities associated with western North Pacific tropical cyclones. This expanded program, called WINDP, is described in reference [3]. The OASP system utilizes the forecast methods in the Wind Probability (WINDP) program mentioned above. The remainder of this report

[1]The NEDS is a remote site communications device capable of requesting and receiving environmental data for display in graphic or alphanumeric form.

describes the development and utilization of the OASP system.

1.2 Description. The OASP system was developed by Systems and Applied Sciences Corporation (SASC) to apply strike/wind probability forecast methods to OTSR. As part of this development, the WINDP program referred to earlier, was revised and adapted for use in the system. Liaison with FNOC ship routers and key personnel was conducted to ensure that the system was operationally oriented. The next three sections of this report describe the OASP system in greater detail.

SECTION 2. MODIFIED WIND PROBABILITY FORECASTS

The WINDP program, mentioned earlier, calculates the probabilities[2] of encountering 30 and 50 kt winds at fixed geographic points based on tropical cyclone warnings issued by the Joint Typhoon Warning Center (JTWC) Guam. This program has been modified by SASC and reconfigured as a set of subroutines for use in the OASP system to calculate these same probabilities for a stationary or moving target at 3 hour intervals during the tropical cyclone warning period (up to 72 hours). For example, a ship in port or underway during all or part of the warning period would be an appropriate target for the modified wind probability calculations. Since it is conceivable that the same ship may be threatened by more than one tropical cyclone along the ship's projected route, the Modified Wind Probability (MODWP) subroutines are configured with the capability of handling a multi-tropical cyclone situation. The MODWP subroutines are an integral part of the OASP system.

[2]Four probability values are calculated for each 3 hour increment during the warning period; the instantaneous probabilities of 30 and 50 kt winds, and cumulative probabilities of 30 and 50 kt winds. The cumulative probabilities are time integrated probability values from the beginning of the warning period.

SECTION 3. SHIP ROUTING APPLICATIONS

The OASP system of programs provides wind probability forecasts for OTSR applications. The approach used in this system is unique in that the level of risk (encountering tropical cyclone winds of given magnitudes) is quantified for a moving target based on the predicted track and intensity for one or more tropical cyclones. This system provides the OTSR personnel and other interested users, such as area commanders and their staffs, with the capability to display, monitor, and evaluate the tropical cyclone wind threat to ships under their cognizance. Furthermore, alternate routes may be generated, evaluated, and displayed for consideration in rerouting ships or to assist in decision making.

SECTION 4. OASP SYSTEM

The OASP system consists of four programs. Each program provides the specific capabilities which are described in the following subsections. Greater detail is provided by references [4] and [5]. It should be noted that the programs complement each other and when viewed as a complete system provides considerable versatility.

4.1 Data Base Program - OASPDB. The program OASPDB provides a rapid assessment of the tropical cyclone threat to OTSR ships. To accomplish this, the program surveys a file of projected OTSR ship routes and, based on the latest JTWC Guam tropical cyclone warning(s), calculates the instantaneous and cumulative probabilities of each ship encountering 30 and 50 kt tropical cyclone winds at 3 hour increments along its projected route during the warning period. Those ships which exceed one or more of the user specified critical probabilities[3] are "flagged" to alert the user of this condition.

The program provides a list of all OTSR ships including the flagged ships, or just the flagged ships, as desired by the user. The projected route and the calculated wind probabilities at 3 hour increments along the route are also listed for each ship. Figure 4-01 shows an example of the listing for a flagged ship. Note that the listing contains the date-time-group (DTG) of the tropical cyclone warning, the ship's international radio call sign (IRCS), the ship's name, and the "flag". The ship's position and the instantaneous and cumulative probabilities of 30 and 50 kt winds are given

[3]Critical probabilities are threshold values determined by the user, which if exceeded represents an unacceptable level of risk. For example, a critical probability of 5% represents a 5% chance of the occurrence of the event or a 95% chance of non-occurrence.

LATEST WARNING DTG IS 80061706

SHIP 2KBJB PIONEER CONTRACTOR ***FLAGGED***

TAU	LAT	LONG	INST PROBS 30KT	INST PROBS 50KT	CUM PROBS 30KT	CUM PROBS 50KT
0	30.0N	145.2E	0.00	0.00	0.00	0.00
3	29.3N	145.2E	0.00	0.00	0.00	0.00
6	28.5N	145.2E	0.00	0.00	0.00	0.00
9	27.8N	145.2E	0.00	0.00	0.00	0.00
12	27.0N	145.2E	0.00	0.00	0.00	0.00
15	26.3N	145.2E	.20	0.00	.20	0.00
18	25.3N	145.2E	1.40	0.00	1.60	0.00
21	24.8N	145.2E	3.90	0.00	5.40	0.00
24	24.0N	145.2E	7.70	.00	12.70	.00
27	23.3N	145.2E	13.30	.04	23.00	.04
30	22.5N	145.2E	16.80	.06	30.00	.08
33	21.8N	145.2E	18.60	.10	34.00	.12
36	21.0N	145.2E	15.52	.20	36.10	.40
39	20.3N	145.2E	10.40	.10	37.90	.70
42	19.5N	145.2E	6.10	.10	37.90	.80
45	18.8N	145.2E	3.00	.00	37.90	.80
48	18.0N	145.2E	1.10	.00	37.90	.80
51	17.3N	145.2E	.50	.00	27.90	.80
54	16.5N	145.2E	.20	.00	38.00	.80
57	15.8N	145.2E	.10	.00	38.00	.80
60	15.0N	145.2E	.00	.00	38.00	.80
63	14.3N	145.2E	.00	.00	38.00	.80
66	13.5N	145.2E	.00	.00	38.00	.80
69	12.8N	145.2E	.00	.00	38.00	.80
72	12.0N	145.2E	.00	.00	38.00	.80

FIGURE 4-01. Sample of Tabular Listing of Flagged Ship

in tabular form at 3 hour increments beginning at warning time (TAU=0). In this example the critical instantaneous and cumulative probabilities of 30 kt winds are set at 5% and 20% respectively. These critical probability values are exceeded and consequently the ship is "flagged".

In addition to the listing, a data base file containing the surveyed OTSR ship's and associated information is generated and saved for use by other OASP programs.

4.2 Dynamic Display Program - OASPDDS. The program OASPDDS generates displays interactively for the FNOC user on a local graphics display terminal or remotely on the Naval Environmental Display Station (NEDS) in reply to an Automatic Response to Query (ARQ) request. These displays may be used for evaluation and briefing purposes. The following products are available:

(a) Geographic background.

(b) Projected route of all OTSR ships within the area of interest for the tropical cyclone warning period.

(c) Projected route of "flagged" OTSR ships for the tropical cyclone warning period.

(d) Forecast track of the tropical cyclone(s) including the present, 12-, 24-, 48-, and 72-hour positions and intensities.

(e) The "danger area" for the tropical cyclone(s) as defined by Annex H of the CINCPACFLT Operations Order 201.[4]

(f) The date-time-group (DTG) when the critical probability values are exceeded for all "flagged"

[4]The "danger area" is determined from the JTWC Guam tropical cyclone warning by constructing the area of 30 kt winds at the warning time, the area of 30 kt winds at the 24-hour forecast position increased by a radius of 135 n mi, and connecting the two areas by tangent lines to produce a contiguous area.

ships and the elapsed time from the warning DTG to the time the critical probability values are first exceeded.

(g) The duration of time the critical probability values are exceeded for all "flagged" ships.

(h) The course and current speed of advance for each ship.

(i) The beginning and ending date-time-group when the ship's "communications window" is in effect.[5]

(j) The ships' average and maximum speeds of advance, if available.

(k) The ships' wind and sea constraints, if available.

The user may select any or all combinations of the above displays. However, it is realized that certain combinations would be impractical, and a more usable procedure would be to select combinations for display in a serial fashion. For example, a display composed of (a), (b), (d) and (e) above would be useful for evaluation or as a briefing aid followed by one composed of (a), (c), (d) and (e). Furthermore, the displays listed as (f) through (k) above are produced in alphanumeric form and may be used as a reference while evaluating the graphic displays. Examples of typical displays are provided as Figures 4-02 and 4-03. The graphic display in Figure 4-02 shows the geographic area of interest, the tropical cyclone track, the "danger area" for the tropical cyclone, and the ships' routes during the warning period up to 72 hours. The symbol "X" is used to denote the beginning, end, and 24-hourly positions of the ships' projected routes. The symbols ">" and "<" are used at 6-hourly intermediate positions and signify eastward and westward component to the movement, respectively. The ships' call signs are also given. In addition to the present, 12-, 24-, 48-, and 72-hour tropical

[5]The "communications window" is the normal time period during which the ship's radio operator is on duty for communications.

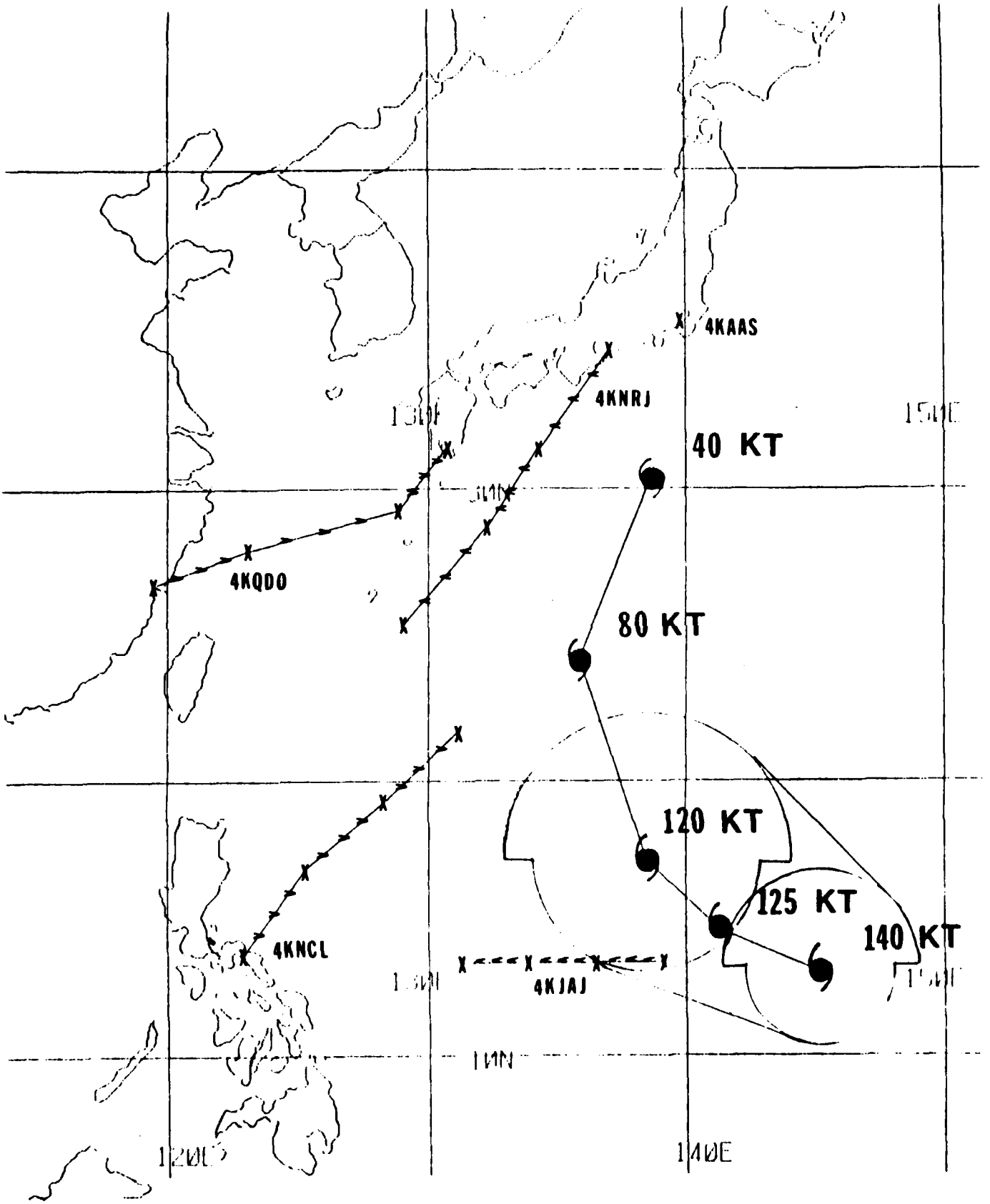

FIGURE 4-02. Portion of graphic display showing geographic background, tropical cyclone track, danger area, and ship tracks.

```
4KJAJ USS DELANEY          AT POS   13.22  138.98 (P)  (U)   ENROUTE
 MAX WIND 35 KTS, MAX WAVES  HEAD 10, BEAM  8, FOLLOW 10 FT.
 COMMUNICATIONS WINDOW  FROM 79061600Z  TO 79061608Z.
 COURSE 270 DEGREES, SOA   6, AVE SOA   6, MAX SOA   6 KTS.
        CRITDTG 7906151200Z ELT   0HRS DUR 42HRS

4KORN HMAS ORION           AT POS    6.21   95.65 (P)  (U)   ENROUTE
 MAX WIND 55 KTS, MAX WAVES  HEAD 10, BEAM 12, FOLLOW 14 FT.
 COMMUNICATIONS WINDOW  FROM 79061600Z  to 79061608Z.
 COURSE 106 DEGREES, SOA  10, AVE SOA  10, MAX SOA  10 KTS.

4KIGE AMERICAN CORSAIR     AT POS   18.13 -167.25 (P)  (U)   ENROUTE
 MAX WIND 45 KTS, MAX WAVES  HEAD 12, BEAM 14, FOLLOW 18 FT.
 COURSE 275 DEGREES, SOA  18, AVE SOA  21, MAX SOA  22 KTS.

4KMFC PIONEER CONTENDER    AT POS   21.31 -158.49 (P)  (U)   ENROUTE
 MAX WIND 45 KTS, MAX WAVES  HEAD 12, BEAM 14, FOLLOW 18 FT.
 COURSE 275 DEGREES, SOA  16, AVE SOA  16, MAX SOA  16 KTS.

4KAEE USNS DE STEIGUER     AT POS   14.74  -99.82 (P)  (U)   ENROUTE
 MAX WIND 55 KTS, MAX WAVES  HEAD 12, BEAM 14, FOLLOW 16 FT.
 COURSE 309 DEGREES, SOA   9, AVE SOA   9, MAX SOA  12 KTS.

4KMEY AMERICAN CHAMPION    AT POS   25.84 -150.44 (P)  (U)   ENROUTE
 MAX WIND 45 KTS, MAX WAVES  HEAD 12, BEAM 14, FOLLOW 18 FT.
 COURSE  56 DEGREES, SOA  15, AVE SOA  16, MAX SOA  17 KTS.

4KAQD USCGC JARVIS         AT POS   56.41 -153.67 (P)  (U)   ENROUTE
 MAX WIND 45 KTS, MAX WAVES  HEAD 12, BEAM 10, FOLLOW 16 FT.
 COURSE  42 DEGREES, SOA   8, AVE SOA   8, MAX SOA   9 KTS.

4KAAS USS KNOWLES          AT POS   35.28  139.67 (P)  (U)   ENROUTE
 MAX WIND 55 KTS, MAX WAVES  HEAD 10, BEAM 12, FOLLOW 14 FT.
 COURSE 180 DEGREES, SOA  14, AVE SOA  15, MAX SOA  15 KTS.
        CRITDTG 7906172011Z ELT  57HRS DUR 15HRS
```

FIGURE 4-03. Portion of alphanumeric display listing ship, position, ship constraints, course, and speeds of advance.

cyclone positions, the present maximum wind speed and forecast wind speeds are shown at these times.

The alphanumeric display in Figure 4-03 shows the information given for several ships, including the ship's international radio call sign (IRCS); name; position at warning time; wind and sea constraints (if available); communications window; course and speed of advance (SOA) in knots; average SOA and maximum SOA (if available); the DTG when one or more critical probabilities are first exceeded; the elapsed time (ELT) from warning time to the time the critical values are first exceeded; and duration that the critical probabilities are exceeded.

4.3 Evaluation Program - OASPEV. The program OASPEV allows the OTSR personnel at FNOC to interact with the OASP system on a graphics display terminal, to display, and to further evaluate the flagged ships. The user has the capability of displaying at the terminal the projected route of a selected flagged ship during the tropical cyclone warning period, the probabilities of 30 and 50 kt winds along the route, and the tropical cyclone(s) which threaten the ship. In addition, the user may optionally overlay the isopleths of the critical instantaneous probability of 30 and/or 50 kt winds at 12 or 24 hour intervals. The user also has a "ZOOM" capability to enlarge a section of the display.

If desired, the user may specify an alternate route for the ship. The wind probabilities of this new route are calculated, evaluated, and displayed for the user. Any number of alternate routes may be evaluated, and based on the results, a route recommendation may be determined.

An example of the tabular display showing the calculated wind probabilities at 3-hour increments is provided in Figure 4-04. Figures 4-05 through 4-07 show examples of the graphic displays.

SPEED= 15.0 KTS DISTANCE= 929.8 NM

BEGINNING DTG - 79092606 WARNING DTG - 79092606

THU	LAT	LONG	INST PROBS 30KT	INST PROBS 50KT	CUM PROBS 30KT	CUM PROBS 50KT
0	32.0N	137.0E	.3	0.0	.3	0.0
3	31.3N	137.2E	.6	0.0	.9	0.0
6	30.6N	137.5E	1.0	0.0	1.8	0.0
9	29.8N	137.7E	1.5	0.0	3.3	0.0
12	29.1N	138.0E	2.3	0.0	5.5	0.0
15	28.4N	138.2E	3.0	0.0	7.8	0.0
18	27.7N	138.4E	3.4	.0	9.6	.0
21	27.0N	138.7E	3.7	.0	10.9	.0
24	26.2N	138.9E	3.6	.0	11.6	.0
27	25.5N	139.1E	3.3	.0	12.2	.0
30	24.8N	139.0E	3.8	.0	12.8	.0
33	24.1N	138.8E	3.9	.0	13.4	.0
36	23.3N	138.6E	3.9	.0	13.9	.0
39	22.6N	138.4E	3.4	.0	14.3	.0
42	21.9N	138.2E	2.9	.0	14.7	.0
45	21.1N	138.0E	2.3	.0	14.9	.0
48	20.4N	137.8E	1.6	.0	15.1	.0
51	19.7N	137.7E	1.0	.0	15.2	.0
54	18.9N	137.5E	.6	.0	15.3	.0
57	18.2N	137.3E	.3	.0	15.3	.0
60	17.5N	137.1E	.2	.0	15.3	.0
63	17.0N	137.0E	.1	.0	15.3	.0

FIGURE 4-04. Sample of tabular display of ship positions, instantaneous and cumulative probabilities at 3 hour intervals.

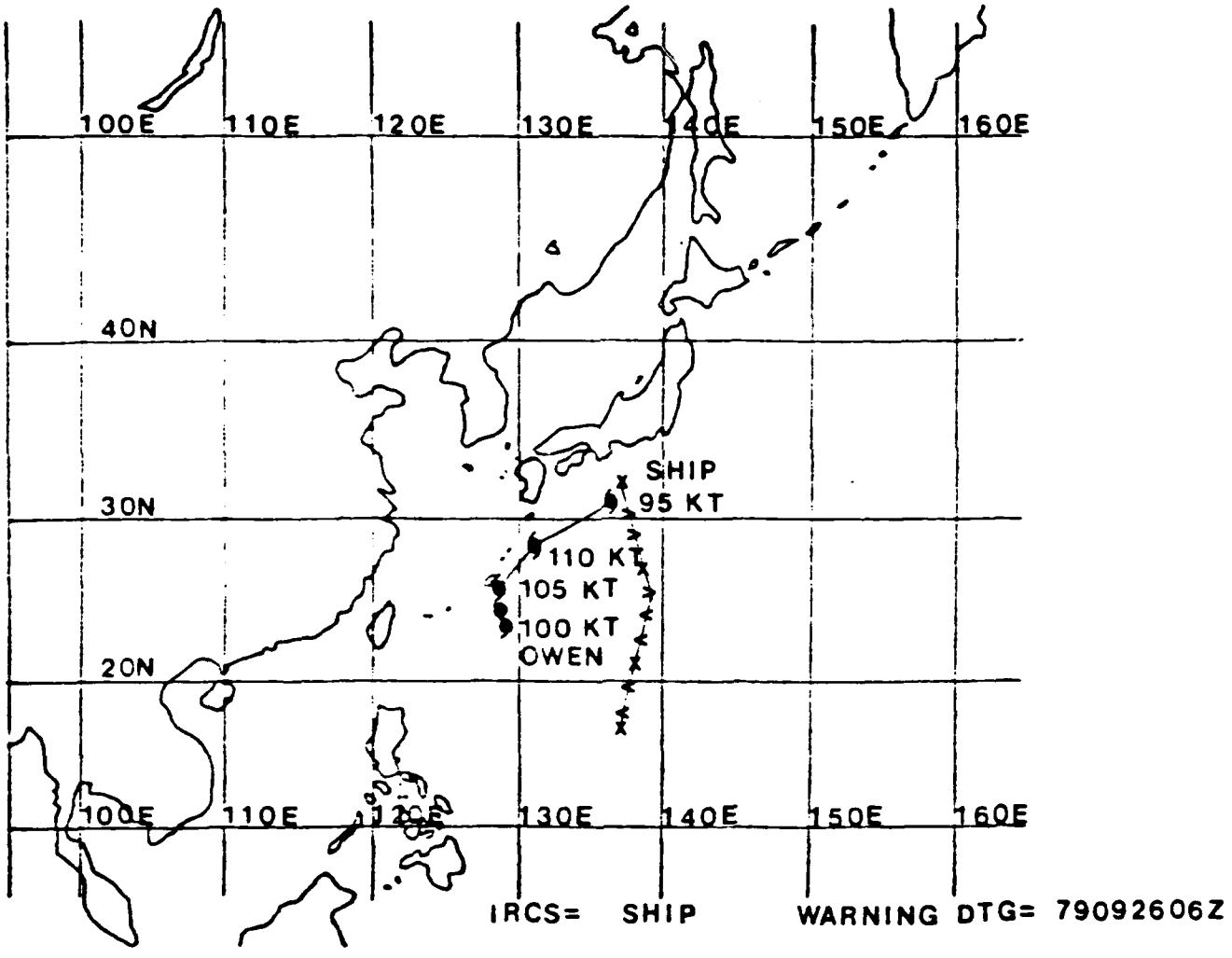

FIGURE 4-05. Graphic Display of tropical cyclone forecast track, ship's track, and background geography. NO ZOOM.

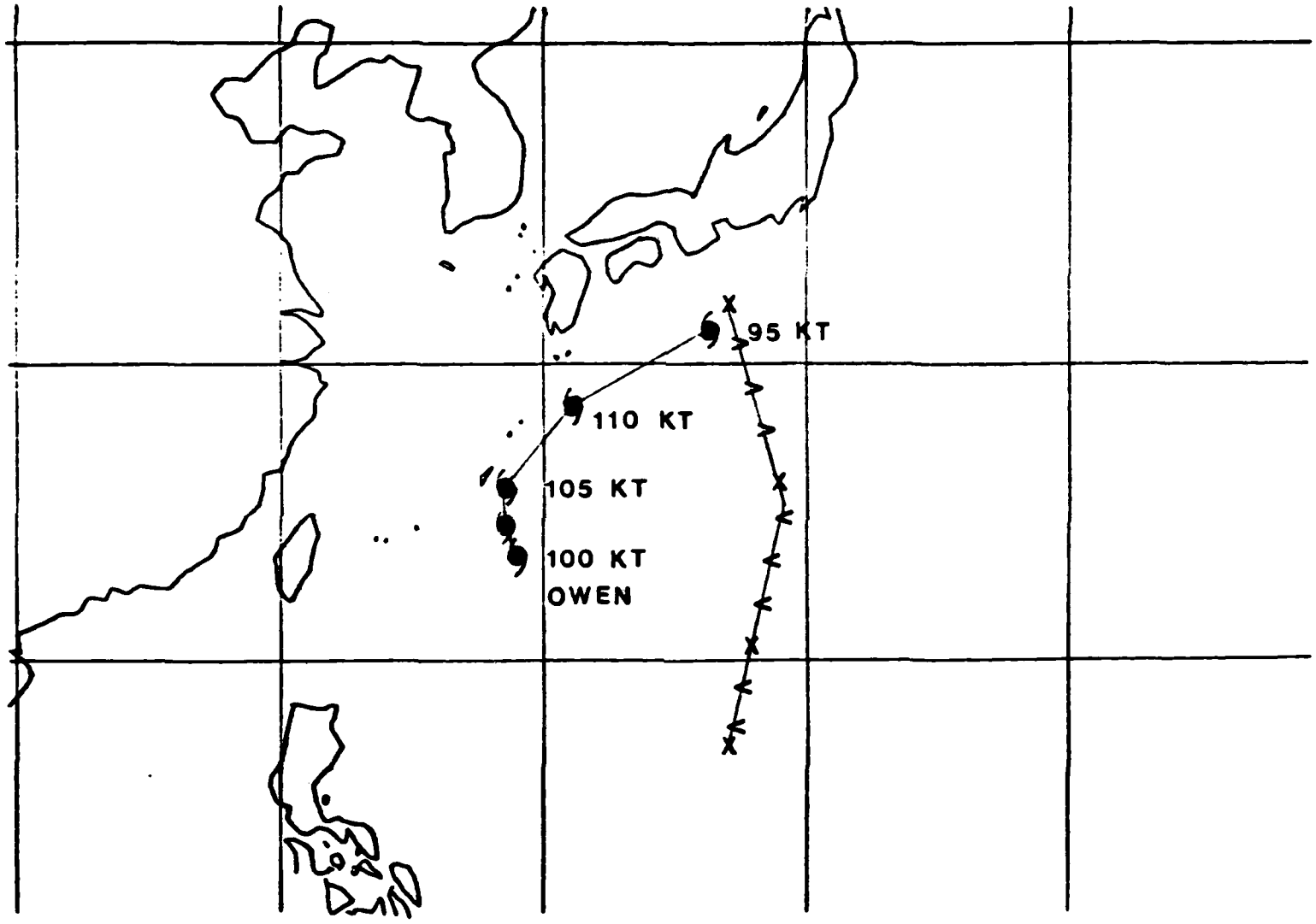

FIGURE 4-06. Graphic Display of tropical cyclone forecast track, ship track, and geographic background. ZOOMED 2X.

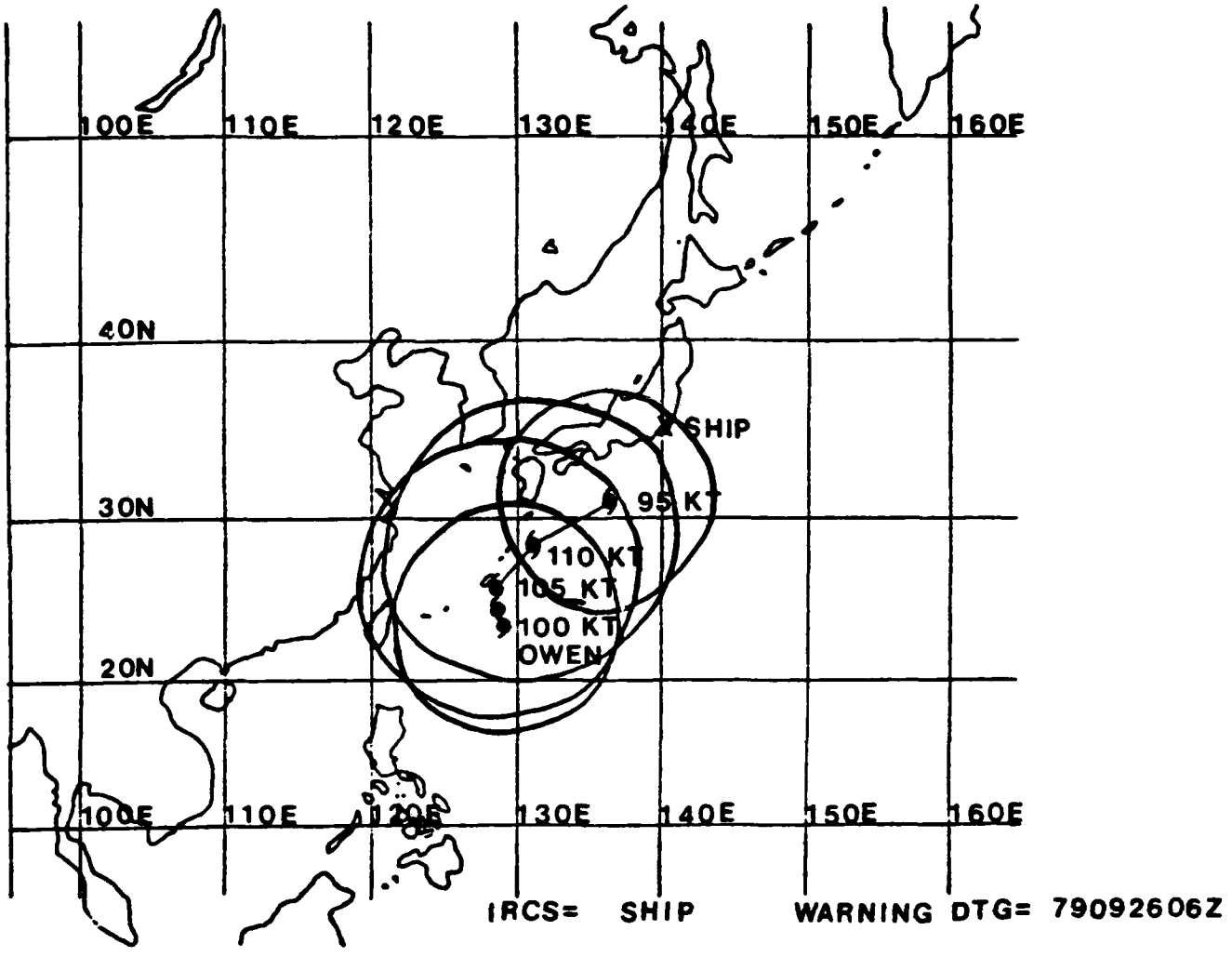

FIGURE 4-07. Graphic Display of tropical cyclone forecast track, 5% probability of 30 kt wind isopleths at 24 hour intervals and geographic background. Ship in port. NO ZOOM.

4.4 Route Program - OASPRT. The program OASPRT provides the OTSR personnel at FNOC the capability of determining the shortest route between two designated points which does not exceed the user specified critical probabilities of encountering 30 and 50 kt tropical cyclone winds. This program, executed interactively at a local graphic display terminal, acts as a short term (for the duration of the tropical cyclone warning period) automatic ship router which finds the best route, based only on wind probabilities, using the parameters specified by the user.

For example, if the ship router wants to be 95% and 97% confident of avoiding 30 and 50 kt winds respectively at any instant during the route, the critical instantaneous probability values of 30 and 50 kt winds should be set for 5% and 3%, respectively. Similarly, if the ship router desires a 80% and 90% probability of avoiding 30 and 50 kt winds respectively for the entire route during the warning period, the critical cumulative probability values of 30 and 50 kt winds should be set for 20% and 10%, respectively. The user designates the ship's average and maximum speeds, the beginning and end points of the route, and the type route (rhumb-line or great circle). The program first checks to see if the initial position exceeds the critical values. Next, the end position is checked over the duration of the warning period when the ship could possibly arrive at that position. If the beginning and end positions do not exceed the critical values, a direct route is evaluated between the two points at various speeds beginning with the ship's average speed. The speed is then reduced decrementally to the minimum speed required to transit between the beginning and end points to see if a speed can be found on the specified route which does not exceed the critical probability values. If no acceptable speed can be found, the ship's speed is incremented in attempting to find a suitable speed until the maximum speed is reached. If the direct route cannot be used

by varying the ship's speed, the program uses an alternate routing technique to circumnavigate the area(s) of critical probabilities of 30 or 50 kt winds. This alternate routing procedure is an innovative method designed for rapid execution. Initially, the program determines the positions along the direct route where the maximum probabilities occur. At these positions, a series of 12 points is constructed perpendicular to and on both sides of the direct route, but only the series of points on the side of the direct route which exhibit decreasing probabilities is used. These points form a network which is then used to generate an acceptable alternate route by constructing and evaluating route segments through the network. As the program builds the route, the route segments are displayed to allow the user to monitor the progress. Once determined, the entire route is displayed at the graphics terminal.

It is possible that no route may be found for the warning period which meets the user's criteria, in which case the parameters may be modified and the process repeated. The displays generated by this program are similar to those of the OASPEV program (see Figures 4-04 through 4-07).

SECTION 5. SUMMARY AND RECOMMENDATIONS

The OASP system applies tropical cyclone wind probability forecast methods to ship routing. This system has great potential as a new approach to the objective evaluation of the tropical cyclone threat to ships and for making timely recommendations to minimize a threat. This approach has the advantage over the standard "danger area" in that the level of acceptable risk is a factor which may be quantified. As a minimum this system provides useful considerations which may be integrated into the decision making process.

Operational evaluation of the OASP system is currently in progress for the latter part of the 1980 tropical cyclone season. As experience is gained with the system and operational procedures are established, certain adjustments and enhancements are a natural result. However, several of the inherent limitations should be discussed and recommendations made.

(1) The system is currently limited to the western North Pacific Ocean. When the wind probability statistics are developed for other areas, this system should be updated to expand its coverage.

(2) Only unclassified ships are processed by this system. With appropriate security, the system may be readily modified to handle classified ships.

(3) Currently, the portion of the ship route under consideration is limited to the forecast period of the tropical cyclone warning (up to 72 hours). Ship routes generally extend beyond this period. Another NEPRF program, GENESIS, which predicts the probability of development of tropical cyclones within 72 hours, will not extend the warning period, but if used in conjunction with the OASP system may provide early threat information before the warnings are issued. Also, consideration should be made to modify the automatic route program (OASPRT) such that a route is generated toward the ship's ultimate destination rather than require the user to specify the end point during the forecast period.

(4) The OASP system does not consider the threat of heavy seas from tropical cyclones. The development of a sea and swell module for inclusion in the system would result in a more complete tropical cyclone threat package. Further work on this aspect of the total tropical cyclone threat is suggested.

(5) Since the OASP system is based on statistical analyses of tropical cyclone official forecast errors, the improvements in forecasting in the years to come should be monitored. The statistical algorithms within the OASP system should be modified appropriately if forecast improvements are shown to be significant.

(6) The complete OASP system is currently limited to the OASP users at FNOC. With the current installation of desktop computers available in the meteorological space on almost all aircraft carriers and USS NEW ORLEANS, the independent shipboard capability for avoidance can become a reality. It is suggested this aspect of research be further explored.

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